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(71)Applicant : NIPPON STEEL CORP
(72)Inventor : FUJIOKA MASAAKI
FUJITA TAKASHI
SHIRAHATA HIROYUKI

(54) PRODUCTION OF HIGH TENSION STEEL EXCELLENT IN TOUGHNESS

(57)Abstract:
PROBLEM TO BE SOLVED: To impart a high strength and high toughness by rolling with controlling a low C and low Mn steel in a specific composition and micronizing the structure.
SOLUTION: The composition is, by weight%, 0.03 to 0.45% C, 0.01 to 0.50% Si, 0.02 to 5.0% Mn, 0.001 to 0.1% Al, and the remainder part is Fe, B and inevitable impurity. The cast billet in this composition is executed with hot machining of rolling, etc., without cooling after casting, or it is once cooled to the room temperature, re-heated to, the temperature range of Ac3 point to 1250°C and it is hot machined to be a steel. In this case, one pass or more than two passes, with continuing interval within 20sec., is executed at a temp. of 500 to 700°C, the rolling strain rate of 0.1 to 20sec, the total strain amount is made as 0.8 to 5 and then it is cooled. Further, it is preferred to forcibly cool to the room temperature to ≤500°C, within 90sec. with the cooling velocity of 2 to ≤20sec., after finishing of hot rolling.

CLAIMS

[Claim(s)]
[Claim 1]At weight %, it is C. : 0.03 to 0.45%, Si : [0.01 to 0.50%,] Mn: 0.02-5.0%, aluminum : 0.001 to 0.1% is contained, . [whether hot working by rolling etc. is performed as it is, without the remainder cooling after casting slab which consists of Fe and inevitable impurities, and] Or once cooling to a room temperature, reheat to A_{C3}

point -1250 ** temperature again, and perform hot working, and it faces manufacturing steel materials, Temperature of not less than 500 ** of 700 ** or less and a strain rate of rolling are made [time between an one pass or paths] into a 0.1-20-/second for processing more than a continuous two pass for less than 20 seconds among a series of hot working, A manufacturing method of high tensile steel excellent in toughness which processes it so that it may become five or less [0.8 or more], and cools the total deformation amount radiationally after that.
[Claim 2]At weight %, it is C. : 0.03 to 0.45%, Si : [0.01 to 0.50%,] Mn: 0.02-5.0%, aluminum : 0.001 to 0.1% is contained, . [whether without the remainder cooling after casting slab which consists of Fe and inevitable impurities, hot working is performed as it is, hot working is not performed, but it cools to temperature to 600 ** - a room temperature once as it is, and] Or it is carried out whether once after-casting cooling to a room temperature, hot working is reheated and carried out to Ac_3 point -1250 ** temperature, hot working is not performed, but it cools to temperature to 600 ** - a room temperature as it is, Heat after that in 700 ** or less temperature of not less than 500 **, and processing more than a continuous two pass for less than 20 seconds for time between an one pass or paths 700 ** or less the temperature of not less than 500 **, And a manufacturing method of high tensile steel excellent in toughness which makes a strain rate of rolling a 0.1-20-/second, processes it on or more 0.8 conditions which become five or less, and cools the total deformation amount radiationally after that.
[Claim 3]A manufacturing method of high tensile steel which was excellent in intensity and toughness carrying out forced cooling with a cooling rate at 2 **/second - 200 **/second or less to temperature below room temperature -500 ** within 90 seconds after an end of hot working after performing the hot working according to claim 1 or 2.
[Claim 4]A manufacturing method of high tensile steel excellent in intensity and toughness characterized by performing tempering at temperature of 300 ** - Ac_1 after performing hot working according to claim 3 and cooling.
[Claim 5]They are Nb:0.001-0.05%, Ti:0.001-0.1%, and V at weight %. : A manufacturing method of high tensile steel excellent in intensity and toughness given in one 1st paragraph of claims 1-4 containing 0.001 to 0.1% of one sort [any], or two sorts or more.
[Claim 6]By weight %, Mo:0.01-1%, nickel:0.01-5%, Cr: 0.01-3%, Cu: 0.01 to 3%, B : A manufacturing method of high tensile steel excellent in intensity and toughness given in one 1st paragraph of claims 1-5 containing 0.0001 to 0.003% of one sort [any], or two sorts or more.
[Claim 7]They are REM:0.002-0.10% and Ca at weight %. : A manufacturing method of high tensile steel excellent in intensity and toughness given in one 1st paragraph of claims 1-6 containing 0.0003 to 0.0030% of one sort [any], or two sorts or more.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]In the steel parts (steel sheets, steel plates, a wire rod, section steel, bar steel, etc.) manufactured by hot-rolling, this invention relates to the manufacturing method of the high tensile steel excellent in its basic characteristic slack

intensity and toughness.
[0002]
[Description of the Prior Art]In recent years, development of steel whose safety it is tougher and is high is called for with the weight saving of a steel part, and severe-izing of the service condition of a structural steelwork. To such a demand, conventionally, the manufacturing method of a steel plate has been improved, grain refining of the crystal grain of a metal texture was attained, and the rolling method for improving the intensity of steel and toughness has been developed. As an example of such a method, what is called a controlled rolling method is raised, and it is shown in JP,63-223124,A, JP,63-128117,A, etc. as a manufacturing method combined with accelerated cooling process.
[0003]In the controlled rolling method shown in these conventional methods, the static recrystallization produced between rolling passes in the recrystallizing temperature region of the austenite (the following, gamma, and brief sketch) of relatively high temperature is used, and grain refining of the gamma grain is carried out. Subsequently, introducing defects, such as a rearrangement, during the crystal of gamma is performed by rolling again in the temperature region (non-recrystallizing temperature region) where waiting and the recrystallization of gamma do not produce that the temperature of a steel plate falls. It is because gamma faces metamorphosing into a ferrite etc. and becomes a nucleation place of transformation generation organizations, such as a ferrite, as well as gamma grain boundary, so such a defect can make many crystal grains generate all at once at the time of cooling and can make a metal texture much more detailed.
[0004]
[Problem(s) to be Solved by the Invention]However, although the particle diameter of the ferrite obtained by such a method is small, it is about at most 5 micrometers, and the method of carrying out minuteness making of the crystal grain more is called for.
[0005]
[Means for Solving the Problem]By the conventional grain-refining means, such as controlled rolling and accelerated cooling, an object [with processing which can obtain a remarkable fine grain which is not obtained and a cooling method] of this invention is to provide a manufacturing method of tough high tensile steel. The following manufacturing methods were created as a means to solve an aforementioned problem.
(1) At weight %, it is C. : 0.03 to 0.45%, Si : [0.01 to 0.50%,] Mn: 0.02-5.0%, aluminum : 0.001 to 0.1% is contained, . [whether hot working by rolling etc. is performed as it is, without the remainder cooling after casting slab which consists of Fe and inevitable impurities, and] Or once cooling to a room temperature, reheat to Ac_3 point -1250 ** temperature again, and perform hot working, and it faces manufacturing steel materials, Temperature of not less than 500 ** of 700 ** or less and a strain rate of rolling are made [time between an one pass or paths] into a 0.1-20-/second for processing more than a continuous two pass for less than 20 seconds among a series of hot working, A manufacturing method of high tensile steel excellent in toughness which processes it so that it may become five or less [0.8 or more], and cools the total deformation amount radiationally after that.
[0006](2) At weight %, it is C. : 0.03 to 0.45%, Si : [0.01 to 0.50%,] Mn: 0.02-5.0%, aluminum : 0.001 to 0.1% is contained, . [whether without the remainder cooling after casting slab which consists of Fe and inevitable impurities, hot working is performed as it is, hot working is not performed, but it cools to temperature to 600 ** - a room

temperature once as it is, and] Or it is carried out whether once after-casting cooling to a room temperature, hot working is reheated and carried out to Ac_3 point -1250 ** temperature, hot working is not performed, but it cools to temperature to 600 ** - a room temperature as it is, Heat after that in 700 ** or less temperature of not less than 500 **, and processing more than a continuous two pass for less than 20 seconds for time between an one pass or paths 700 ** or less the temperature of not less than 500 **, And a manufacturing method of high tensile steel excellent in toughness which makes a strain rate of rolling a 0.1-20-/second, processes it on or more 0.8 conditions which become five or less, and cools the total deformation amount radiationally after that.
[0007](3) A manufacturing method of high tensile steel which was excellent in intensity and toughness carrying out forced cooling with a cooling rate at 2 **/second - 200 **/second or less to temperature below room temperature -500 ** within 90 seconds after an end of hot working after performing hot working of above-mentioned (1) or (2) statements.
(4) A manufacturing method of high tensile steel excellent in intensity and toughness characterized by performing tempering at temperature of 300 ** - Ac_1 after performing hot working given [above-mentioned] in (3), and cooling.
[0008](5) They are Nb:0.001-0.05%, Ti:0.001-0.1%, and V at weight % further. : Manufacturing method of high tensile steel excellent in intensity and toughness given in one 1st paragraph of above-mentioned (1) - (4) containing 0.001 to 0.1% of one sort [any], or two sorts or more.
[0009](6) By weight %, further Mo:0.01-1%, nickel:0.01-5%, Cr: 0.01-3%, Cu: 0.01 to 3%, B : Manufacturing method of high tensile steel excellent in intensity and toughness given in one 1st paragraph of above-mentioned (1) - (5) containing 0.0001 to 0.003% of one sort [any], or two sorts or more.
[0010](7) They are REM:0.002-0.10% and Ca at weight % further. : It is in a manufacturing method of high tensile steel excellent in intensity and toughness given in one 1st paragraph of above-mentioned (1) - (6) containing 0.0003 to 0.0030% of one sort [any], or two sorts or more.
[0011]Hereafter, this invention is explained in detail. First, when a grain-refining method by the conventional controlled rolling was examined from a metallurgy standpoint, as it mentioned above, it is thought that it is what is mainly depended on the following effects.
** Use static recrystallization produced between rolling passes in a recrystallizing temperature region of austenite (the following, gamma, and brief sketch) of relatively high temperature, and carry out grain refining of the gamma grain.
** Introduce many defects, such as a rearrangement, during a crystal of gamma by rolling in a temperature region (non-recrystallizing temperature region) which recrystallization of gamma which is low temperature further comparatively does not produce.
** Since gamma faces metamorphosing into a ferrite etc. and becomes a nucleation place of a transformation generation organization, defects, such as the above gamma grain boundaries and a rearrangement, make a metal texture detailed.
[0012]Among these, each of ** - ** provides a nucleation place of transformation generation organizations, such as a ferrite, makes a crystal grain diameter of a final ferrite detailed by this, makes a ferrite grain number which generates all at the time of a transformation to a ferrite from austenite increase, and attains minuteness making. However, in minuteness making using such a transformation, since transformation

starting temperature from austenite of usual steel to a ferrite is a temperature in which diffusion of an iron atom in 750 to 800 ** and steel is comparatively quick, grain growth is quick, and only a crystal grain which is about at most 5 micrometers is obtained. Although temperature of a ferrite transformation can be compulsorily reduced with forced cooling, in such a case, it becomes from a viewpoint of toughness -- a ferrite to generate is needlelike or bainite generates -- with an organization which is not preferred.
[0013]Then, this invention persons overthrow a limit of grain refining using the above transformations, A ferrite of a remarkable fine grain as a method of obtaining A ferrite, austenite or a ferrite, and perlite, By processing a mixed organization of bainite and martensite on proper conditions, cooling, and producing and cheating out of recrystallization (dynamic recrystallization or recovery) under [in the middle of rolling] a roll for a ferrite grain, It found out that it can reach to an extreme of a ferrite crystal grain as shown in drawing 1, and it could be supposed that it is detailed, these phenomena were investigated and analyzed, and a manufacturing method of high tensile steel excellent in the toughness of claims 1-7 was invented.
[0014]The main point of art used as the basis of this invention is as follows. The minuteness making of the crystal grain can be carried out to 1 micrometer or less with dynamic recrystallization (or recovery) of a ferrite. In order to acquire a detailed and uniform ferrite grain at this time, conditions about following processings and cooling are required. First, an organization before processing which produces and cheats out of recrystallization is a mixed organization with the 2nd phase of a ferrite, austenite or a ferrite, perlite, bainite, martensite, etc. Since a ferrite is divided by that a ferrite becomes is easier to be processed because of a deformation resistance difference between the 2nd phase and a ferrite, and processing with the 2nd phase when recrystallizing, distraction and, this is extended very thinly, and it is considered because grain growth after recrystallization and union are also pressed down.
[0015]Next, about temperature which processes it, in order to obtain the aforementioned organization before processing, must be the temperature with which a ferrite and the 2nd phase coexist, and it is necessary to be Ac_3 - a room temperature but, and, Since the 2nd phase depends an organization of a ferrite subject who exists in a minute amount on carrying out dynamic recrystallization, an organization molar fraction of a ferrite is required for a chief aim of this invention to some extent (about at least 60%), but it is required for attaining this stably to be 700 ** or less. As for working temperature, it is desirable that it is 700 ** or less also from a viewpoint which controls grain growth behind dynamic recrystallization by processing. However, if working temperature is too low, it is required to process it at temperature of not less than 500 ** from such a viewpoint by which atomic diffusion is delayed remarkably and dynamic recrystallization is not produced stably.
[0016]Next, a distortion amount and rate of strain in processing need to set up so that dynamic recrystallization may be produced stably and a crystal grain diameter after recrystallization can be made detailed. Drawing 2 is a stress-strain curve when steel which contains Ti 0.14%Si[C-0.25%]-1.2%Mn-0.01%Nb-0.01% is processed on condition of this invention and a fine grain organization like drawing 1 is obtained. It is presumed that softening under processing considered to be based on dynamic recrystallization has arisen in this, produced softening repeatedly further, and recrystallization has arisen repeatedly. In such a case, in the 1st softening, it is thought

mostly that a metal texture becomes a fine grain and a uniform thing, and is in a stationary state mostly after that.

[0017]Therefore, 0.8 or more distortion [the above distortion amount is required to some extent to obtain a desirable organization with dynamic recrystallization, and] in a temperature requirement of this invention was checked experimentally. It is easy to produce dynamic recrystallization so that this is small about rate of strain, but minuteness making of a crystal grain diameter cannot be performed. When rate of strain were too large, dynamic recrystallization did not arise, but it turned out that load at the time of processing also becomes very large. Then, as a result of dynamic recrystallization's arising stably and examining a range in which minuteness making of a crystal grain is possible, it turned out that the ranges of suitable rate of strain are 0.1-20.

[0018]Next, if time between paths is made into a short time even if an one pass performs the above-mentioned processing and it carries out above a two pass, the effect will not change fundamentally. It is because recovery in the meantime will be small and distortion by many paths will accumulate mostly in a temperature requirement of this invention, if working temperature makes time between paths less than 20 seconds so quickly [it is comparatively low and / recovery between paths]. Finally, although a very detailed ferrite can be obtained immediately after processing by the above-mentioned processing, after an end of processing, if it cools promptly, control of grain growth of a ferrite of this will be enabled, and it makes it possible to obtain the more outstanding characteristic. When austenite exists as the 2nd phase at the time of processing, with water cooling, austenite turns into martensite and bainite, and steel can be strengthened, but ductility and toughness may be degraded. In such a case, manufacture of outstanding steel of intensity, toughness, and ductility can be performed by stopping water cooling in the middle of cooling, or performing tempering after water cooling.

[0019]Below, a reason for limitation of each ingredient and manufacturing conditions is explained. C is an element effective in strengthening steel, and the 2nd phase that this application makes indispensable does not generate it stably while intensity sufficient at less than 0.03% is not obtained. On the other hand, weldability will be degraded if the content exceeds 0.45%. Although Si is effective as a deoxidizing element and a reinforcing element of steel, the effect does not exist at less than 0.01% of content. On the other hand, if 0.5% is exceeded, a surface disposition of steel will be spoiled.

[0020]Mn is an element effective in strengthening of steel, and effect sufficient at less than 0.02% is not acquired. On the other hand, the processability of steel will be degraded if the content exceeds 5.0%. Although added as a crystal grain at the time of reheating to a deoxidizing element and an austenite temperature region, if aluminum does not have the effect and 0.1% is exceeded, it will degrade a surface disposition of steel in less than 0.001% of content. Since each of Ti, V, and Nb(s) functions effectively in respect of minuteness making of a crystal grain, and precipitation strengthening by a little addition, they may be used in the range which does not degrade the toughness of a weld zone. It carries out in Ti and V and a maximum of the addition is made into 0.05% by Nb 0.1% from such a viewpoint. A minimum of the addition is made into 0.001% because it is ineffective less than [this].

[0021]Each of Cu, nickel.Cr(s), Mo, and B is elements which raise the hardenability of steel, and, in the case of this invention, can raise intensity of steel by the addition. However, excessive addition is limited to 0.01%<=Cu<=3.0%, 0.01%<=nickel<=5.0%,

0.01%<=Cr<=3.0%, 0.01%<=Mo<=1.0%, and <= [0.0001% of] B<=0.003% in order to spoil toughness and weldability of steel. It is because it is ineffective in each minimum of Cu, nickel, Cr, and Mo to have made a minimum of B into 0.0001% 0.01% less than [this].
[0022]It limits for REM, and although REM and Ca are effective in detoxication of S, when there are few additions, the effect does not exist, and excessive addition limits for Ca to 0.0003 to 0.0030% 0.002 to 0.10% in order to spoil toughness. In addition, 0.02% or less and 0.008% or less of content of P and S which are inevitable impurities is desirable respectively.
[0023]Next, it attaches and states to manufacturing conditions in this invention. Since this invention is effective also about slab cast in what kind of casting condition, it is not necessary to specify a casting condition in particular. Processing in the state where the 2nd phase used as the basis of this invention exists, It heats to a once perfect austenite region (temperature more than Ac_3), and cools to temperature to 600 ** - a room temperature a case (claim 1) where it is processed between 700 ** - 500 ** of the cooling process, and once, and a case (claim 2) where it is processed by a subsequent temperature rise process can be considered.
[0024]In the case of the former, rolling may be started after reheating a cast piece once cooled to a room temperature at Ac_3 point -1250 **, even if it starts hot working as it is after casting a cast piece, without cooling. Temperature of reheating was made beyond Ac_3 point here because an austenite texture in which a metal texture of steel at the time of rolling is perfect less than [this] did not become. It is because a metal texture of steel makes it big and rough that a maximum of reheating temperature was 1250 ** at temperature beyond this and desired toughness is not acquired.
[0025]. [whether processing in the case of the latter is reheated and carried out in 700 ** or less temperature of not less than 500 **, once cooling to temperature to 600 ** - a room temperature as it is, without processing slab between casting post heating, and] Or. [whether once performing hot working as it is after casting and cooling to temperature to 600 ** - a room temperature, it reheats and carries out in 700 ** or less temperature of not less than 500 **, and] Or what is necessary is just to carry out by reheating in 700 ** or less temperature of not less than 500 **, after cooling to temperature to 600 ** - a room temperature, without performing hot working or performing hot working, after reheating a cast piece cooled to a room temperature once [after-casting] at Ac_3 point - 1250 **.
[0026]Even when it is direct after casting, after performing casting post processing, or also after cooling after casting and reheating to an austenite region again, It is because a metal texture of steel will turn into an organization of perlite which is mainly a ferrite and the 2nd phase, bainite, martensite, etc. and will fulfill main affairs of this invention, once it cools from an austenite region to temperature to 600 ** - a room temperature. Since processing and reheating which precede cooling to temperature to 600 ** - a room temperature make detailed a ferrite crystal grain at the time of cooling to 600 ** - a room temperature, they act advantageously to this invention.
[0027]Next, it is necessary to perform processing which produces dynamic recrystallization of a ferrite at 700 ** - 500 **. This is because a volume fraction of austenite is too large, and even if it can carry out the minuteness making of the ferrite portion and the target organization is not obtained above 700 **. [it] In a portion which

it received processing by a ferrite portion and austenite which received processing on the same conditions, and metamorphosed into a ferrite, it is because the ferrite portion of a crystal grain diameter is quite more detailed. A crystal grain tends to become large and the lower possible one of working temperature is so preferred that working temperature becomes high also in a ferrite portion which carried out dynamic recrystallization simultaneously. However, if working temperature is too low, it will be hard to produce atomic diffusion and recrystallization will become difficult to happen. In such a case, it becomes only carrying out flat, and a detailed particle size regulation organization is not obtained, but anisotropy generates a processed ferrite grain in the characteristic of steel. So, in order for recrystallization of a ferrite to arise stably, it is required to process it in a not less than 500 ** temperature region.

[0028]Recrystallization arises in the whole organization during processing in this temperature requirement, and a distortion amount in processing at 700 ** - 500 ** needs for a crystal grain diameter after recrystallization to be detailed. In order for recrystallization to arise in the whole organization, a fixed quantity of processing amounts are above required, and 0.8 or more distortion is required for the total distortion amount by processing of a series [viewpoint / such]. If a distortion amount is secured 0.8 or more, and a distortion amount is large, it is difficult large to secure five or more distortion amounts in processing of the usual rolling etc., although it is moderate. So, a maximum of distortion to give was set to 5 in this invention.

[0029]If rate of strain are [that it is easy to produce dynamic recrystallization] so large that it is small, it will be hard to produce a strain rate at the time of processing. On the other hand, when rate of strain are small, reduction (recovery) of a rearrangement under processing is quick, as a result a crystal grain diameter obtained after recrystallization is large and rate of strain are large, a crystal grain diameter is small. If both the ease of producing of such dynamic recrystallization and a crystal grain diameter after recrystallization are taken into consideration, a proper field exists in rate of strain. Rate of strain under processing were limited [more than 0.1/second] below a 20-/second from such a viewpoint. It is because a detailed crystal grain cannot be obtained in less than a 0.1-/second even if time which rolling takes is too long, recovery of a rearrangement arises in during this period, many rearrangements cannot be introduced into alpha but dynamic recrystallization arises. Rate of strain at the time of rolling were carried out below a 20-/second because it was difficult to produce dynamic recrystallization in more than a 20-/second in a temperature region (700 ** - 500 **). When an one pass performs the above-mentioned rolling or many paths perform, it is required to make time between paths into less than 20 seconds. This is because recovery of a ferrite will advance between paths and a summation effect of distortion will not be acquired, if time between paths is made into 20 seconds or more.

[0030]Next, how to perform forced cooling is succeedingly explained to a series of hot-rolling which makes dynamic recrystallization produce. First, the following two points can be considered about an effect of forced cooling. First, it is for a detailed ferrite obtained after processing to grow with grain growth between subsequent radiational cooling, and to control reduction of the validity by cooling compulsorily. Maintain at temperature below the transformation starting point (Ac_3 point) in an equilibrium situation a small amount of austenites which exist as the 2nd phase when processing it by a cooling process from austenite with un-metamorphosing, and especially the 2nd reason

causes them, By making a transformation produce from a state where a degree of undercooling is high, driving force of a nucleation of a transformation organization is raised remarkably, It is the purpose of the first point to make many crystal grains generate all at once, and to attain grain refining of after-transformation organizations, such as a ferrite and perlite, and austenite receives processing, and such a grain-refining effect shows up notably, when defects, such as many rearrangements, are introduced in an austenite grain. By producing a transformation at low temperature by cooling, an austenite portion can be made into a detailed ferrite, and bainite and martensitic structure with comparatively high intensity, and intensity of steel can be improved.

[0031]In order to attain strengthening by demonstrating the grain-refining effect of a ferrite by forced cooling from these viewpoints, and making bainite and martensite generate a little further in this invention depending on the case, By claim 3, succeedingly, forced cooling was started to hot-rolling which makes dynamic recrystallization produce within 90 seconds, and it has specified cooling even temperature beyond a room temperature - a less than 500 ** room temperature in a second in 2-200 ** /to it. A reason for limitation is explained below.

[0032]First, having made a cooling start into less than 90 seconds from an end of processing, It is for preventing a detailed ferrite formed with dynamic recrystallization at the time of rolling becoming big and rough with grain growth, and is because the effect will not be demonstrated to the maximum extent, but it will seldom change to a case where it cools radiationally after processing and a water-cooled effect does not show up notably in a cooling start after exceeding this. It is because having made cooling finishing temperature into less than [room temperature -500 **] next has too high a temperature at temperature of not less than 500 ** and grain growth cannot be controlled to a detailed ferrite obtained by processing, and is because having used beyond a room temperature cannot carry out cooling to temperature not more than this easily by the usual water cooling.

[0033]When a part which was austenite metamorphoses into martensite with dramatically high intensity and raises intensity of steel too much after processing it, when the above cooling is performed, degradation of remarkable toughness may produce claim 4 simultaneously. In such a case, it can be considered as steel which was excellent in intensity and toughness by performing tempering at temperature of 300 more ** - Ac_1 after cooling. Tempering is what is carried out for the purpose of improving toughness which deteriorates remarkably by generation of martensite, It has too low a temperature that tempering temperature was not less than 300 ** less than [this], and it is because dissolution carbon cannot be deposited easily for a short time, Below Ac_1 point carried out tempering temperature because a transformation will arise and toughness will deteriorate on the contrary for a strong fall or unevenness of an organization, if Ac_1 point is exceeded.

[0034]

[Example]Next, the example of this invention shows the validity of this invention. Table 1 shows the ingredient of steel of an example. In front, it is shown that the steel shown by O seal is comparison steel, and the underline has shown the item which is not in agreement with this invention. Next, the intensity and toughness which were acquired about the steel plate manufactured by various manufacturing conditions using steel of such an ingredient are shown in Table 2 and 3 with manufacturing conditions. As

intensity, yield strength (YS (kgf/mm^2)) and tensile strength (TS (kgf/mm^2)) are shown. Toughness showed the ductile brittle transition temperature (vTrs (**)) in a Charpy impact test. In [any] steel, it turns out that intensity and toughness have improved notably processing at 500-700 ** which is the main business of this invention as compared with what did not perform the processing. The manufacturing conditions shown in this invention method all show the clearly good characteristic compared with the comparison method. It is possible to manufacture the high tensile steel which was excellent in intensity and toughness by this invention method, and this invention is effective.

[0035]

[Table 1]

表1　鋼の成分（重量%）

鋼	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	Nb	V	Ti	B	N	Al	REM	Ac_3	Ac_1
A	0.20	0.35	0.80	0.011	0.005	−	−	−	−	−	−	−	−	0.0030	0.030	−	835	724
B	0.14	0.25	1.00	0.010	0.006	−	−	−	−	−	−	0.008	−	0.0025	0.032	−	845	720
C	0.14	0.20	1.42	0.008	0.003	−	−	−	−	0.025	−	−	−	0.0020	0.028	−	862	713
D	0.17	0.40	1.33	0.007	0.004	−	−	−	−	0.015	−	0.010	−	0.0022	0.030	−	844	720
E	0.06	0.30	1.60	0.012	0.002	0.20	0.30	−	−	−	−	−	−	0.0030	0.035	0.0010	869	710
F	0.13	0.25	1.45	0.014	0.008	−	−	−	−	−	−	0.007	0.0011	0.0015	0.040	−	848	717
G	0.10	0.25	1.30	0.012	0.004	0.30	0.60	0.25	0.50	−	0.028	−	−	0.0037	0.033	−	866	710
H	0.001	0.20	1.50	0.005	0.003	−	−	−		−	−	0.010	−	0.0023	0.028	−	881	728
I	0.07	0.20	1.20	0.008	0.005	−	−	−	0.50	0.08	−	−	−	0.0032	0.032	−	904	745
J	0.10	0.25	1.32	0.007	0.006	−	−	0.20	1.50	−	−	0.010	0.0024	0.0028	0.030	−	913	704

注）アンダーラインは本発明外

[0036]

[Table 2]

表２　実施例の製造条件

No.	鋼	スラブ厚 (mm)	再加熱条件		500～700℃の圧延に先立つ圧延の条件			鋳造または再加熱または圧延後の冷却条件		500～700℃の加熱条件		500～700℃の圧延（加工）の条件						
			温度 (℃)	時間 (分)	開始温度 (℃)	終了温度 (℃)	終了板厚 (mm)	冷却方法	終了温度 (℃)	加熱温度 (℃)	保持時間 (分)	仕上り板厚 (mm)	(*1) ε	(*2) $\dot{\varepsilon}$ (S^{-1})	圧延開始温度 (℃)	圧延終了温度 (℃)	パス数	パス間時間 (s)
1	A	300	1150	120	950	780	75	放冷	680	なし		10	2.0	5	680	700	1	－
2	A	〃	1150	120	950	740	75	放冷	600	なし		6	2.5	5	600	620	2	3
3	A	〃	直送圧延		1050	900	75	放冷	200	700	5	10	2.0	5	680	700	1	－
4	A	〃	なし		なし			放冷	RT	700	5	25	2.5	5	700	700	3	3
5	A	〃	1150	120	950	780	25	放冷	RT	500～700℃の加工を実施せず ＊								
6	B	〃	1200	90	1000	850	75	放冷	720	なし		25	1.2	12	700	700	1	－
7	B	〃	直送圧延		930	800	75	放冷	RT	650	30	34	0.8	12	650	660	1	－
8	B	〃	なし		なし			放冷	RT	650	30	60	1.6	12	650	660	2	10
9	B	〃	950	30	なし			放冷	RT	650	30	25	2.5	2	650	650	3	10
10	B	〃	950	60	なし			放冷	RT	650	30	3	4.6	0.5	650	600	5	10
11	B	〃	直送圧延		1000	820	37	放冷	RT	650	30	25	0.4＊	10	650	650	1	－
12	B	〃	なし		なし			放冷	RT	650	30	25	2.5	30 ＊	650	660	2	2
13	B	〃	なし		なし			放冷	RT	650	30	25	2.5	0.01＊	650	550	2	2
14	C	250	なし		なし			放冷	RT	720	5	20	2.5	7.5	700	700	3	5
15	C	〃	なし		なし			放冷	RT	700	5	20	2.5	7.5	700	700	3	5
16	C	〃	1000	60	なし			放冷	RT	700	5	20	2.5	7.5	700	700	3	5
17	C	〃	1000	60	なし			放冷	RT	600	5	20	2.5	7.5	600	600	3	5
18	C	〃	なし		なし			放冷	RT	550	5	20	2.5	7.5	550	550	3	5
19	C	〃	なし		なし			放冷	RT	400 ＊	5	20	2.5	7.5	400 ＊	400 ＊	3	5
20	C	〃	なし		なし			放冷	RT	780 ＊	5	20	2.5	7.5	780 ＊	760 ＊	3	5
21	D	300	なし		なし			放冷	700	なし		15	3.0	5	700	700	7	2
22	D	〃	直送圧延		1000	750	150	放冷	700	なし		15	1.5	5	700	700	1	－
23	D	〃	なし		なし			放冷	700	なし		15	3.0	5	700	700	3	5
24	D	150	900	60	なし			放冷	RT	680	20	20	2.0	5	680	700	1	－
25	D	〃	900	60	なし			放冷	RT	680	20	20	2.0	5	680	700	3	1
26	D	〃	なし		なし			放冷	RT	680	20	20	2.0	5	680	700	3	10
27	D	〃	なし		なし			放冷	300	680	20	20	2.0	5	680	700	1	－
28	D	〃	1100	60	950	780	20	放冷	RT	500～700℃の加工を実施せず ＊								
29	D	300	1100	60	なし			放冷	760 ＊	なし		15	3.0	5	760 ＊	750 ＊	3	5
30	D	150	なし		なし			放冷	RT	680	20	20	2.0	5	680	700	3	100 ＊
31	D	〃	なし		なし			放冷	RT	680	20	20	2.0	5	680	700	1	－
32	D	〃	なし		なし			放冷	RT	690	20	20	2.0	5	690	700	1	－
33	D	〃	なし		なし			放冷	RT	680	20	20	2.0	5	680	700	1	－
34	E	250	1100	90	1000	850	150	放冷	RT	650	60	15	2.5	7.5	650	660	5	20
35	E	〃	1100	90	970	780	75	放冷	650	なし		15	1.6	7.5	650	660	2	20
36	E	〃	1100	90	970	850	15	放冷	RT	500～700℃の加工を実施せず ＊								
37	F	〃	なし		なし			放冷	RT	700	0	20	2.5	5	700	700	3	5
38	F	〃	1150	120	950	800	75	放冷	620	なし		15	1.6	5	620	620	1	－
39	F	〃	1150	120	950	800	15	放冷	RT	500～700℃の加工を実施せず ＊								
40	G	〃	なし		なし			放冷	RT	600	60	20	2.5	5	600	620	3	5
41	G	〃	1050	120	950	800	75	放冷	600	なし		15	1.6	5	600	620	2	5
42	G	〃	1050	120	950	800	15	放冷	RT	500～700℃の加工を実施せず ＊								
43	H ＊	〃	なし		なし			放冷	RT	700	30	20	1.6	10	700	700	3	10
44	I ＊	〃	なし		なし			放冷	RT	700	30	20	1.6	10	700	700	3	10
45	J ＊	〃	なし		なし			放冷	RT	700	30	20	1.6	10	700	700	3	10

（＊1）εは本発明の５００～７００℃の加工　　＊：本発明の範囲外

（＊2）$\dot{\varepsilon}$は各パスの平均歪速度

[0037]

[Table 3]

表3　実施例の製造条件と機械的特性

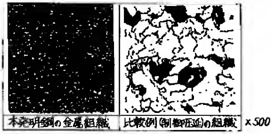
No.	鋼	圧延後の冷却条件			焼戻し条件		機械的特性			フェライト粒径 (μm)
		圧延終了からの時間 (s)	冷却終了温度 (℃)	冷却速度 (℃/s)	焼戻し温度 (℃)	焼戻し時間 (分)	YP (MPa)	TS (MPa)	vTrs (℃)	
1	A	0	350	60	なし		515	680	−125	<1
2	A	放冷			なし		475	615	−110	2.3
3	A	30	350	60	なし		514	642	−125	<1
4	A	0	400	40	なし		503	591	−125	<1
5	A	500 ～ 700℃の加工を実施せず*			なし		399	532	− 40	14
6	B	0	400	40	なし		466	647	−120	1.5
7	B	10	400	40	なし		477	611	−120	2.0
8	B	10	400	25	なし		521	635	−130	1.3
9	B	10	400	40	なし		522	621	−145	<1
10	B	10	400	100	なし		535	623	−145	<1
11	B	10	400	40	なし		465	574	− 60	21
12	B	10	400	40	なし		483	618	− 60	著しい偏平粒
13	B	10	400	50	なし		475	583	− 75	8.3
14	C	30	<200	50	なし		391	620	−125	1.2
15	C	30	<200	50	なし		418	635	−130	< 1.0
16	C	30	<200	50	なし		411	637	−145	< 1.0
17	C	30	<200	50	なし		451	645	−135	< 1.0
18	C	30	<200	50	なし		418	643	−120	< 1.0
19	C	30	<200	50	なし		453	647	− 70	著しい偏平粒
20	C	30	<200	50	なし		500	705	− 20	7.5
21	D	0	400	50	なし		467	640	−120	<1
22	D	0	<200	50	なし		498	662	−118	1.3
23	D	0	<200	50	550	30	490	620	−135	1.3
24	D	45	350	50	なし		463	662	−130	<1
25	D	45	350	50	なし		480	658	−130	<1
26	D	45	350	50	なし		474	632	−120	1.5
27	D	放冷			なし		470	618	−110	2.2
28	D	500 ～ 700℃の加工を実施せず*			なし		380	540	− 35	18
29	D	45	350	50	なし		396	695	− 20	5
30	D	45	350	50	なし		496	605	− 50	18 (偏平)
31	D	200 *	350	50	なし		472	621	−115	2.0
32	D	45	<200	50	520	20	496	620	−140	1.5
33	D	45	<200	50	750 *	30	402	730	− 20	12
34	E	20	300	30	なし		479	623	−135	< 1.0
35	E	20	300	30	なし		480	635	−130	< 1.0
36	E	500 ～ 700℃の加工を実施せず*			なし		437	583	− 40	21
37	F	10	400	30	なし		501	663	−115	< 1.0
38	F	10	400	30	なし		496	675	−105	< 1.0
39	F	500 ～ 700℃の加工を実施せず*			なし		489	632	− 40	12
40	G	10	<200	20	なし		497	710	− 80	< 1.0
41	G	10	<200	20	500	30	491	682	−100	< 1.0
42	G	500 ～ 700℃の加工を実施せず*			なし		506	693	− 40	10
43	H *	10	<200	40	なし		360	432	− 55	26
44	I *	10	<200	40	なし		482	667	+ 20	<1
45	J *	10	<200	40	なし		515	830	+ 40	<1

＊：本発明の範囲外

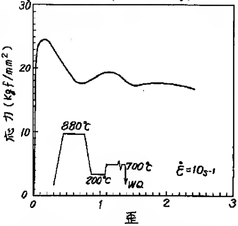
[0038]
[Effect of the Invention]As stated above, according to this invention, the high-tensile steel sheet excellent in intensity and toughness can be provided cheaply.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]



[Drawing 1]The mimetic diagram showing the detailed ferrite obtained with dynamic recrystallization (or recovery)



[Drawing 2]It is an explanatory view of change of the stress-strain curve by dynamic recrystallization (or recovery).